

Notes on the Biology of *Comperiella unifasciata* Ishii and its host *Aspidiotus destructor rigidus* nov. subsp.

by

Dr A REYNE.

Comperiella unifasciata Ishii (fam. Chalcididae, subfam. Encyrtinae) was described by T. Ishii (1) in 1925 as a parasite of *Pseudoaonidia duplex* Ckll (the camphor-scale) in Southern Japan. In 1926 the insect was re-described and figured by H. Compere (2) after material from Japan.

In the Dutch East Indies *Comperiella unifasciata* is only known as a parasite of *Aspidiotus destructor rigidus* nov. subsp., a scale-insect which caused great damage to the coconut-palms in the island of Sangi (Nth Celebes) in the years 1925—1927. In the infected area, which comprised in Oct. 1925 about 200 palms near the village Taroena but at the end of 1927 some 400.000 in the northern part of Sangi, about 30000 trees were killed while the others were severely damaged and produced no fruits. The scale-insect was studied by the author from 1927-1929, when he was zoologist to the Institute of Plant-diseases at Buitenzorg (Java); the following observations on its parasite *Comperiella unifasciata* were made during these investigations.

Aspidiotus destructor rigidus nov. subsp. is distinguished from the typical *Aspidiotus destructor* Sign., found in all coconut-growing countries, by the following features:

1) The cuticle is extremely tough as is easily shown by lifting the insect from the leaf with a needle. Other distinct morphological differences have not been found in comparing the subspecies *rigidus* with many strains of typical *destructor*, collected in several localities of the Dutch East Indies and in other parts of the world (America, Africa, Pacific).

2) The life-cycle of the subspecies *rigidus* is about 1,5 times as long as that of the typical *destructor* according to several breeding experiments made at Buitenzorg (Java) and on the island of Sangi (Nth Celebes). In these experiments *destructor* and *rigidus* were bred side by side on young coconut-palms as well as on bananas.

3) The white egg-skins, left under the scales after emergence of the larvae, accumulate near the pygidium in *rigidus*, forming a white semi-lunar figure, while in the typical *destructor* the white egg-skins are scattered around the whole body of the scale-insect. By this feature mature colonies of *rigidus* and *destructor* can be easily distinguished, even with the naked eye (3). This different distribution of egg-skins is due to the following facts. In *rigidus* the

eggs are deposited in a very advanced stage of development (legs, antennae, mouth-spines and eyes completely developed) and hatch within 4 days. Usually no more than 10—12 eggs are found under the scale near the pygidium where the egg-skins accumulate. In the typical *destructor* the eggs are deposited early, usually before the reversion of the embryo when the germ-band is still in the S-stage. They hatch after 6—8 days. The whole space below the scale is filled up with eggs (40—60); the female turns round during oviposition by movements of its pygidium. After emergence of the larvae the egg-skins lay scattered around the whole body of the female.

4) *Rigidus* is found on the leaves of the mangosteen (*Garcinia mangostana* L.) and can be easily bred on this food-plant while this is impossible with the typical *destructor*.

Aspidiotus destructor Sign. is found everywhere in coconut-plantations in the Dutch East Indies; it seems to occur in all coconut-growing countries. The subspecies *rigidus* is hitherto only known from Western and Central Java and some localities in North and South Celebes. In North Celebes, including the island of Sangi, the invasion of *rigidus* is of recent date; the parasite *Comperiella unifasciata*, found in Java and South Celebes (around Macassar), was absent there before 1927 when it was introduced by the author. In 1934 and 1935 a severe outbreak of *Aspidiotus destructor rigidus* was reported from the island of Bali. Outside the Dutch East Indies *rigidus* is probably found in the Pelew Islands according to samples collected by Mr. T. Yoshino, govt-entomologist in these islands. Samples sent to me from Mauritius and Sierra Leone (Africa), Guam and Yap (Pacific) belong to the typical *destructor*. Entomologists from the Philippines and Fiji Islands, Dr. L. B. Uichanco and Mr. R. W. Payne, whom I showed colonies of typical *destructor* and *rigidus* at Buitenzorg (Java), told me that they had not seen this subspecies *rigidus* before and that the species injurious to coconut-palms in their country was the typical *destructor*. The same applies to outbreaks of *Aspidiotus* in young coconut-plantations which I have seen during my stay in Dutch Guiana (Sth America) between 1918 and 1924. Descriptions in literature of *Aspidiotus destructor* in Ceylon, Br. India, the Philippines and other countries refer to the typical *destructor* and not to *rigidus*.

Outside the *rigidus*-area, mentioned above, *Comperiella unifasciata* has nowhere be found in the Dutch East Indies. This parasite is very common in the neighbourhood of Buitenzorg (Java) where *rigidus* is the dominating type of *Aspidiotus* on coconut-trees (of 11707 coconut-leaflets with *Aspidiotus* collected from 12 March to 15 August 1929 96.2 percent were provided with *rigidus* and only 3.8 percent with typical *destructor*). In examining 578 samples of coconut-leaves infected with *rigidus*-colonies 499 or 86 percent were found with scale-insects infected by *Comperiella unifasciata*

(March-Aug. 1929). At the same time of 95 samples with the typical *destructor* only 3 percent showed infection by this parasite. Introduction of this parasite into the Fiji Islands, where *Aspidiotus destructor* was abundant but where the subspecies *rigidus* does not occur, did not meet with success according to Taylor (4). It seems that the typical *destructor* is only accidentally infected with *Comperiella* when *rigidus* is also present; in the Dutch East Indies this parasite is only found in the *rigidus*-area which is still very limited. Breeding experiments as described below seem to show that *destructor* is a less suitable host than *rigidus* though artificial infection is easily performed.

In a few cases *rigidus*-colonies were found with 80—90 percent parasitism by *Comperiella unifasciata*, but generally the percentage was much lower. In Buitenzorg the average percentage was 4.9 (July-Aug. '29), 2.6 (Oct. '29) and 5.6 (Dec. '29) in samples (containing each 20—30 leaflets) collected from 50, 10 and 10 localities respectively. The percentage of parasitism can be easily examined by scraping the scale-insects from the leaf in a suitable glass-dish filled with alcohol. A plancton-cell of 20 cc, as described by Kolkwitz (5), was used for this purpose; a good pocket-lense (8 x and 16 x) is sufficient for examination. For a quick inspection in the field the infested leaflets were held to the light and examined with a hand-lense (6—8x). The pupae and older larvae of *Comperiella* are clearly visible in this way; even a parasitism of 1 : 1000 is seldom overlooked with this method. According to my experience *Riley*-cases were not suitable for quantitative determinations in this case; during my travels in Nth Celebes and the Moluccas I used black bags instead of the unwieldy wooden cases, 30 of these bags with glass-tubes could be easily packed in one kerosene-tin.

The parasites were introduced into Sangi by infecting coconut-seedlings with *Aspidiotus destructor rigidus* which after due time were artificially infected with *Comperiella unifasciata*. The coconut-seedlings thus prepared were shipped to Sangi in large cages; on arrival they were placed in the crowns of tall coconut-palms in the infested area. About half a year later *Comperiella* was already abundant on these infection-trees. The parasites were recovered from trees at a distance of 10, 30, 40, 45, 50, 70 and 100 metres from the original source of infection, but not on more remote trees. One year after the introduction the parasites were found at a distance of 1000 metres from the original infection-trees. Several other introductions of *Comperiella* from Buitenzorg have been made in the same way. Usually the parasites could be found in the neighbourhood of the infection-trees $\frac{1}{2}$ —1 year afterwards. In one case the parasites had spread in 6 months to a distance of 600 metres. Two and a half year after the first introduction into Sangi 53 leaf-samples (about 1200 leaflets) with *rigidus* were collected in 39 villages which were distributed over the whole island. Of these 53 samples 49 (i.e. 92 percent) contained *Comperiella unifasciata*.

The island of Noesa about 6500 metres from the East coast of Sangi was at this time also infested by *Aspidiotus destructor rigidus*, parasitised by *Comperiella unifasciata*. The larvae of *Aspidiotus*, which have just emerged and not yet attached themselves to the leaf, are transported by the wind as was demonstrated by exposing glass-plates smeared with "tangle-foot" (sticky substance to catch insects) in the Bay of Taroena. From heavily infested trees a constant rain of mobile larvae is falling down as can be shown by the same method. It seems likely that the western point of Noesa became infected with *Aspidiotus* by agency of the wind and that *Comperiella* was transported in the same way. The East coast of Sangi was at that time heavily infested by *Aspidiotus*. In these islands strong winds come almost exclusively from a western direction. The maximum percentage of parasitism in each of the 53 above-mentioned samples from Sangi was determined for the separate leaflets contained in each sample. The average of the 53 maxima was about 12 percent. The average parasitism for all 1200 leaflets has not been calculated, but it was certainly not above that mentioned for Buitenzorg.

Breeding experiments were made to determine the length of the life-cycle of *Comperiella unifasciata* and to find out in which stage *Aspidiotus* is infected. As far as I knew, nothing was known at that time (1927—1929) about the biology of this *Comperiella*. It was only in 1935 that Taylor (4) published his observations on the parasites and enemies of *Aspidiotus destructor* in Java, made on that island in 1926. Taylor gives a detailed description of the different stages of *Comperiella unifasciata* and determined their duration. He found that the whole life-cycle from oviposition to emergence comprises about 27 days (duration egg-stage 5, larval stages 16, pupal stage 6 days). The propagation is mainly parthenogenetic; Taylor only once found a male, I have never observed them. He states that only female scales which have past the second moult and which are nearly or quite mature are attacked by it; a few eggs of *Aspidiotus* have then attained their maximum size. Occassionally the scale-insect is attacked after it has laid a few of its eggs. The development of *Aspidiotus* ceases as soon as it is parasitised; its progeny is generally suppressed.

All these statements are in accordance with my own observations. I found, however, that in my experiments even the youngest stages of *Aspidiotus* could be infected. Infection of older stages which had already deposited some of their eggs was also successful. As Taylor was not acquainted with the existence of the subspecies *rigidus*, whose biology differs considerably from that of the typical *destructor*, and as I have bred *Comperiella unifasciata* in *rigidus* as well as in typical *destructor* a short account of my breeding experiments seems not to be superfluous.

In these experiments young coconut-palms with clean leaves were infected with *Aspidiotus* (either *rigidus* or typical *destructor*) by

fastening leaf-pieces with mature colonies (by means of paper-clips) during one day on their leaflets. These leaflets were enclosed in a sleeve-like envelope of fine gauze, open on both ends and supported by two rattan-hoops. One end of this sleeve was bound to the main-rib and the other end to a stick placed near the tip of the leaflet. When *Aspidiotus* had attained the desirable stage of development, it was infected by *Comperiella* enclosed in a small vial which during 1—2 days was bound to the leaflet. The *Comperiella* being slow in their movements generally deposited their eggs in the scale-insects quite near the mouth of the vial. The results of the breeding-experiments are shown in the table below.

From the table it appears that under favourable conditions the life-cycle of *Comperiella unifasciata* (from oviposition to emergence) is completed in 26—28 days. The same was found in some less complete experiments not mentioned in the table. In *rigidus* (II c) 27 days, *rigidus* (II b and c) 27 days, *destructor* (II a and b) 28 days, *destructor* (III c) 28 days.

Artificial infection of the first larval stage of *Aspidiotus* is successful in *rigidus* as well as in typical *destructor*. The number of offspring is large and a large percentage of pupae emerges (cp B 12 and B 32) but the duration of development is longer. It seems that *Comperiella* feeds principally on the ovaria which are only fully developed in the third larval stage of *Aspidiotus* and that the development of *Comperiella* is arrested for some time when the infected larva is too young.

Though artificial infections in the typical *destructor* succeed well the percentage of emergence of the *Comperiella*-pupae is lower than in the subspecies *rigidus*. Of 160 pupae in *destructor* 108 (67.5 percent) emerged, of 416 pupae in *rigidus* 364 (87.5 percent); cp No 8 and 9 in the table. The number of offspring in *destructor* is much smaller than in *rigidus* (cp No 14). It seems likely that the lower percentage of emergence and the lower number of progeny in *destructor* is due to the fact that it is a less suitable host than *rigidus*. As stated above in the field *Comperiella unifasciata* is only occasionally found in *destructor* in the *rigidus*-areas and never outside them. The principal cause of this difference is probably the shorter duration of the third larval stage in *destructor*. Only $4\frac{1}{2}$ — $5\frac{1}{2}$ days after reaching this stage eggs are deposited by *destructor* while in *rigidus* this takes 12—17 days (observations in Buitenzorg, Java, and Taroena, Sangi). It is remarkable that in all infected colonies *Comperiella* emerges only after the first *Aspidiotus*-larvae (from non-infected individuals) have emerged (cp No 16).

In *rigidus* infection is still possible at the end of the third larval stage (cp B 36). Only in a few cases in these experiments *Comperiella*-holes were found in *Aspidiotus* that had already produced larvae according to the egg-skins found under the scale. In the field, however, it is a rule that parasitised *Aspidiotus* do not lay eggs.

In the field *Comperiella*-larvae, even the youngest stages, are only found in the third larval stage of *Aspidiotus*, as is also stated by Taylor. Further it is observed in the field that *Comperiella* emerges only after the emergence of the first *Aspidiotus*-larvae in the same colony.

From the table (No 4 and 7) it is evident that in *destructor* *Comperiella* emerged when the scale-insects had an average age of 51 days, in *rigidus* when the average age was 60 days. It seems therefore that *destructor* of $51-27 = 24$ days and *rigidus* of $60-27 = 33$ days are most suitable for infection; in both cases the scale-insect is in the beginning of the third larval instar at this age.

It is likely that in most cases the next generation of *Aspidiotus* is still too young to be infected when *Comperiella* emerges (cp No 16). In the field it is often seen that the progeny of a heavily infected colony has escaped infection by *Comperiella*.

It is remarkable that the number of progeny is very low, even when *Comperiella* is left on the *Aspidiotus*-leaves (No. 14, B 23). In an experiment with *destructor* (II a and b; not mentioned in the table), where 26 *Comperiella* were left on the *Aspidiotus*-colony, the progeny was only 65, i.e. $2\frac{1}{2}$ per *Comperiella*. According to Taylor oviposition in *Comperiella* lasts at least 7 days. In my experiments most parasites were dead or had disappeared after being left for 2 days in the scale-colonies. The progeny in B 23 and B 33 is about equal, though in the first case *Comperiella* was permanently left in the *Aspidiotus*-colonies and removed in the second case after one day.

As *Comperiella unifasciata*, a special parasite of *Aspidiotus destructor rigidus* in Java and Sth Celebes, was introduced into Sangi and Nth Celebes with the intention to combat the damage done by *rigidus* in these islands, we may ask whether this parasite is able to prevent or check an outbreak of its host. Taylor was of opinion that insect-enemies are not the most important controlling factors of *Aspidiotus* in Java. Though parasites and predators are abundant wherever outbreaks occur the latter appear to be checked by climatic or other factors and not by insect-enemies. He often found 90 percent of parasitism insufficient to prevent the scale-insect from increasing. The internal parasites which he introduced from Java into Fiji in 1927 were a failure (in the case of *Comperiella unifasciata* this is quite intelligible as its host *rigidus* does not occur in Fiji. R.). Afterwards he found that the Coccinellid *Cryptognatha nodiceps* Mshl. introduced by him from Trinidad into Fiji in 1928, was a remarkable success as a means of controlling *Aspidiotus destructor*.

I share Taylor's opinion that parasites and predators are not an efficient control of *Aspidiotus destructor rigidus* in Java and that 90 percent of parasitism is often insufficient to prevent the scale-insect from increasing. In the case of *Comperiella unifasciata* I am able to explain why this parasite cannot be an efficient check

of *Aspidiotus destructor rigidus* as I have studied the rate of multiplication in both insects. We have to distinguish between two phases of multiplication and spreading in the case of *rigidus*. 1) Multiplication on the same leaf or tree in which the mobile larvae reach their place of attachments chiefly walking. 2) Multiplication in which the larvae are spread from tree to tree by the wind and other agents.

One individual of the scale-insect in question may give rise to a progeny of 50 on a clean vigorous leaf. In small colonies of about 100 individuals density becomes already a limiting factor. The number of progeny in this case is generally not more than 10 per individual. The same figure may be accepted for rapid multiplication on the tree according to several observations in the field. A parasitism of at least 90 percent would be needed to reduce the rate of multiplication from 10 to 1. In reality the parasitism must be higher than 90 percent. If in a colony of 100 *Aspidiotus* 90 are killed the progeny will be more than $10 \times 10 = 100$, as there is more room for attachment by the destruction of 90 parents. One example from my breeding experiments may illustrate this. A colony of *rigidus* (118 females, age 33 days) was infected with *Comperiella*; 78 percent became parasitised (March). In May and June the colony was not flourishing. In July, however, there was again a rapid multiplication, also of the parasites so that the parasitism in the beginning of August rose above 90 percent. The leaflet had become (after breeding during half a year *Aspidiotus* on it) wholly yellow and was exhausted in spite of the high percentage of parasitism. If parasites were absent a leaflet could be used at least during 3 generations of *rigidus* (about 5 months); usually a fourth generation of scale-insects could be bred on it. From this example it is clear that a parasitism of 80—90 percent by *Comperiella* had no favourable effect in protecting the leaf from the damage done by *rigidus*. A parasitism of 90 percent by *Comperiella unifasciata* is seldom observed, only in small groups of *rigidus*; the average percentage of parasitism is usually much lower as was stated above for Buitenzorg and Sangi.

In spreading from tree to tree the rate of multiplication during outbreaks may rise to 2, accepting that the increase of the number of scale-insects is proportional to the increase of the number of infected trees. A parasitism of 50 and 90 percent would reduce in this case the rate of multiplication probably to about 1.5 and 1.1 since the number of larvae carried to other trees would diminish to 50 and 10 percent of the number expected when parasitism was absent. The figures are probably somewhat lower than 1.5 and 1.1 since more room is left on the original trees where *Aspidiotus* is partially destroyed by parasites.

From these observations it is clear that *Comperiella unifasciata* is unable to control an outbreak of *Aspidiotus destructor rigidus* efficiently and that it is certainly unable to prevent it. It will only

slow down the rate of multiplication to some measure. The severe outbreak in the island of Sangi ended at the close of 1927, but this was not due to the introduction of *Comperiella* since it was then only established in a few localities in small colonies. The emerging *Aspidiotus*-larvae and those just settled all died from some unknown cause, presumably internal weakness of the scale-insects, induced by deterioration of their own food-supply; the heavily infested trees lose most of their chlorophyll and are soon in a starving condition.

With reference to the relation host-parasite I might call attention to a phenomenon which is often mis-interpreted. When the host starts to multiply rapidly the percentage of parasitism (ratio parasites : hosts) will diminish. On the other hand when decline of the outbreak sets in, the percentage of parasitism will rise. It is incorrect to conclude in the first case that the parasites are diminishing and in the second case that they are increasing. If parasitism is expressed in absolute figures instead of relative ones (ratio parasite : host) we get quite another picture as is shown by the following example. *Aphelinus chrysomphali* Mercet, a common parasite of both *destructor* and *rigidus*, seemed to be very scarce in the infested area in Sangi. The average parasitism was about 1 : 1000, while in places where there is no outbreak of *Aspidiotus* it is often 10—30 percent. The conclusion that the parasite was scarce was wholly wrong, it was one of the most abundant insects in the infested area as could be easily demonstrated by exposing glass-plates smeared with "tangle-foot". The density of *rigidus*-colonies is about 30 per square cm. A full-grown coconut-palm has (according to many measurements) a leaf-surface of about 200 square metres (only the lower leaf-surface taken into account) so that such a tree will harbour at least 60 millions of *Aspidiotus* and 60000 *Aphelinus* if the parasitism is 1 : 1000.

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